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# MODEL AND STRUCTURAL ANALYSIS OF HYPOID GEAR

**D. V. RAMANA REDDY[1] & G. REVANTH KUMAR[2]**

[1]*Assistant Professor, Department of Mechanical Engineering, Vardhaman College of Engineering, Hyderabad, Telangana, India*

[2]*Research Scholar, Department of Mechanical Engineering, Vardhaman College of Engineering, Hyderabad, Telangana, India*

***ABSTRACT***

***The objective of the present work is to analyze the structural behaviour of differential hypoid gear. The gear is made up of different alloy materials as compared with the conventional metallic materials. The alloy materials can withstand adequate strength and are suitable for being a better alternative for replacing of metallic gears. The alloy materials considered here are Aluminium Alloy, Titanium Alloy and Monel 500 and compared with the Ni-Cr steel. In this work, an attempt has been made to replace the metallic gears of Ni-Cr steel with the suitable alloy materials. For the analysis purpose, the solid model is created by using CATIA V5R20 software, and ANSYS 17.1 is used to determine the total deformation, Von-Mises stress and equivalent elastic strain for the different materials at different speeds.***

***KEYWORDS: Hypoid Gear, Von Mises Stress, CATIA V5R20 & ANSYS 17.1***

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**Original Article**

## INTRODUCTION

The motion from one shaft to another shaft may be transmitted with the help of belts, ropes, chains. These methods are mostly used when the two shafts having long centre distances, but when the distance is small between two shafts, then the gears are used for transmission of motion from one shaft to the another shaft. When using of gears for motion transmission, there is no slip and accurate motion is transmitted than compared to the belts, ropes, and chains. Now days, gear is used in many applications like watches, lifting cranes, automobiles etc. In automotive industry, the differential gears play an important role in power transmission as well as in the handling of the rear wheels motion. The efficiency of a gear drive depends on the type of material used & reducing the stress in the system. This reason is the scope for alternative materials, to be suitable for manufacturing of gear. The main considerations while selection of a gear material is the ability to withstand the high stresses and temperature during continuous operation. Here, an alloy material is well suitable as they have better material properties, such as lower density with high specific stiffness and strength, corrosion resistant, high impact energy absorption and less weight than compared to the conventional metallic materials and so on. Based on these factors, gears are made with alloy materials. In this present work, the analysis is conducted on the different alloy materials, to find the best material for manufacturing of gears in the gear box at higher speeds, based on the results of analysing stress, displacement and strain. For this reason, the modelling of the hypoid gear assembly was made in CATIA V5R20 design software and FEM based structural analysis, the results were carried out on the ANSYS 17.1 analysis tool.

## METHODLOGY

- To develop the Hypoid gear assembly model, by using CATIA V5 R20 design software and Design data book
- Import the geometry in Ansys 17.1 analysis software

- Select the Conventional metallic materials and alternative alloy materials
- Here we are comparing the Aluminium Alloy, Titanium Alloy, and Monel 500 and compare with the Ni-Cr steel materials
- Apply the boundary conditions and forces in the geometry
- To calculate the Von Mises stresses, strains and displacements by using ANSYS17.1 Analysis software
- Analyze the static structural behaviour of differential hypoid gear, in all the materials under different torques.

## FEM ANALYSIS OF THE GEAR

FEM (Finite element method / analysis) is a computer based analysis. Based on this analysis software, the strength and behaviour of structures during the given boundary conditions are calculated. In the FEM software, to convert the geometry in infinite degrees of freedom to the finite degrees i.e. the entire geometry is divided into the small elements, which is called nodes, and, by connecting of these nodes formed elements. Finite element analysis is generating the numerical solution of geometry. Based on these results, to study the behaviour mechanical components i.e. von-misses stress, total deformation and equivalent strain are acquired by discretizing the mechanical components into a small finite number of building blocks (known as elements). Finite element method is the cheap and easy technique as compared to the theoretical and experiment methods, to find out the stress developed in a pair of gears. Model has been prepared in CATIA V5R20 design software and saved in iges file format, and these file have been imported into ANSYS 17.1 analysis software for further analysis.

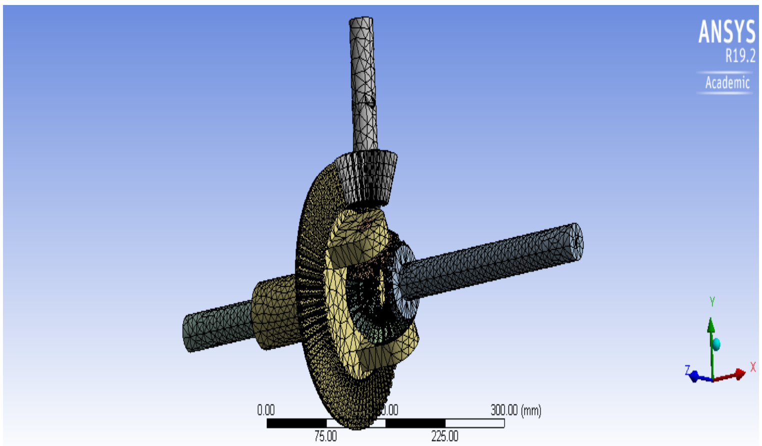



**Figure 1: Meshing of Differential Gear Box in ANSYS.**

## MATERIAL PROPERTIES

The various mechanical properties of the selected conventional metallic and alloy materials are given in the below table.

**Table 1: The Various Materials Considered for Analysis**

| Properties | Ni-Cr Steel | Aluminium Alloy | Monel 500 | Titanium Alloy |
|---|---|---|---|---|
| Model type | Linear elastic Isotropic | Linear elastic Isotropic | Linear elastic Isotropic | Linear elastic Isotropic |
| Failure Criteria | Max Von-Misses stress | Max Von-Misses stress | Max Von-Misses stress | Max Von-Misses stress |
| Yield Strength | 172.339MPA | 280MPA | 280MPA | 930MPA |
| Tensile Strength | 413.613MPA | 310MPA | 310MPA | 1070MPA |

| | | | | |
|---|---|---|---|---|
| Youngs Modules | 180000MPA | 71000MPA | 179000MPA | 96000MPA |
| Poisson's Ratio | 0.28 | 0.33 | 0.32 | 0.36 |

## TORQUE CONSIDERATION

For the analysis purpose, three different toque conditions were considered; the purpose of considering is to see the real situation of the stress produced in both the material and their ability to carry the power relative to each other. All the boundary conditions and factors were taken, according to the AGMA standards and all units are in SI units. The different torques considered is given in the table below.

**Table 2: Different Torque Considered**

| Sl. No. | Torque (N-M) | RPM |
|---|---|---|
| 1 | 490 | 1800 |
| 2 | 390 | 3600 |
| 3 | 130 | 5400 |

## STATIC STRUCTURAL ANALYSIS

The static structural analysis is an analysis for finding the stress, deformation and strain. These analyses were used for studying the behaviour of the structure under steady loading conditions (i.e. how the stress acting on the geometry), while ignoring inertia and damping effects, such as those carried by loads, varying with respect to time. All types of non-linearities are allowed such as large deformations, plasticity, creep, stress stiffening, contact elements etc. These results will determine whether the structure will withstand for the applied external loads or not. If the stress values obtained in this analysis within the limit i.e. known as safe working stress and the results of stress crosses the safe working stress, then the material cannot be suitable for the manufacturing of the component because, the material cannot withstand the stress, so failure of the structure takes place in the static condition itself. To avoid such failure, this analysis is necessary. In this work, the FEA analysis software was used to study the structural behaviour of the different alloy materials under the given boundary conditions. Based on the boundary conditions to determine the total deformation, equivalent Von-mises stress, for each alloy material and then the comparison were done with the previous published journals. In the present work, the generation of FEM based structural analysis results shows the behaviour of Ni-Cr steel, Aluminium Alloy, Titanium Alloy, Monel 500 alloy materials at different torque conditions. The results of the static structural were as shown below:

For the Ni-Cr Steel Torque = 490 N-m

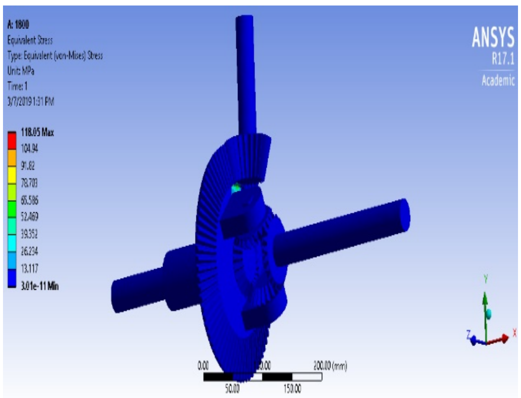



**Figure 2: Von Mises Stress For Ni-Cr Steel = 118.05 MPA.**

at Torque = 390 N-m

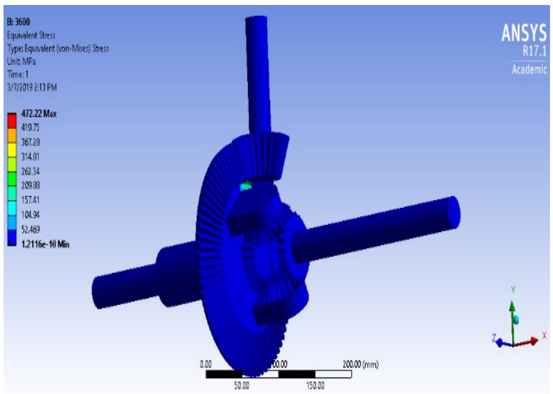



**Figure 3: Von Mises Stress For Ni-Cr Steel = 472.22MPA.**

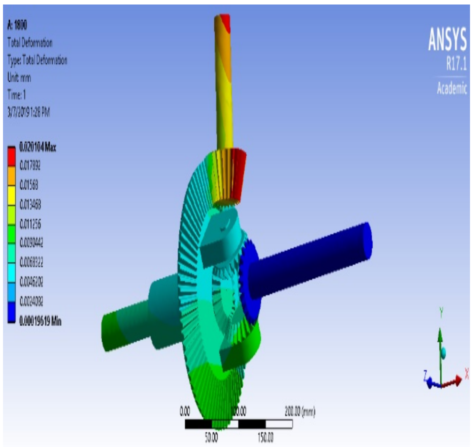



**Figure 4: Total Deformation for Ni-Cr steel = 0.020104 mm.**

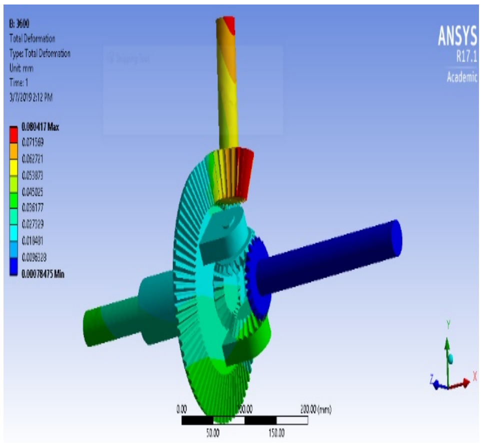



**Figure 5: Total Deformation for Ni-Cr Steel = 0.080417 mm.**

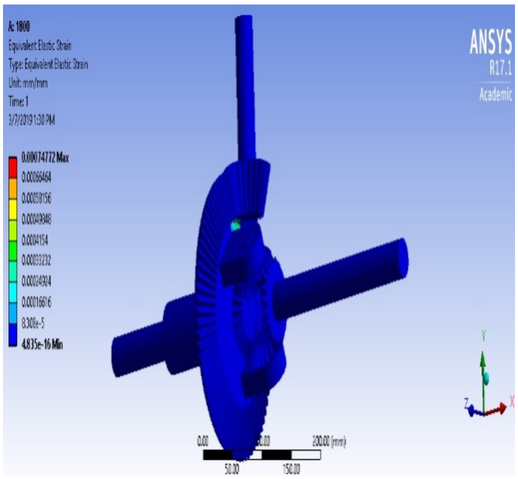



**Figure 6: Maximum Strain for Ni-Cr Steel = 0.00074772 At Torque =130 N-m.**

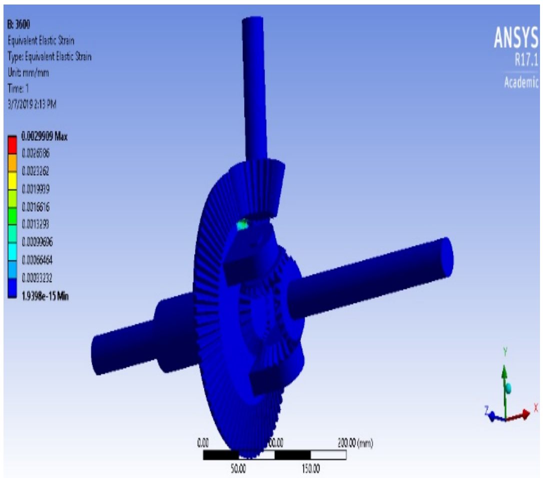



**Figure 7: Maximum Strain for Ni-Cr Steel = 0.00299 For the Titanium Alloy Torque = 490 N-m.**

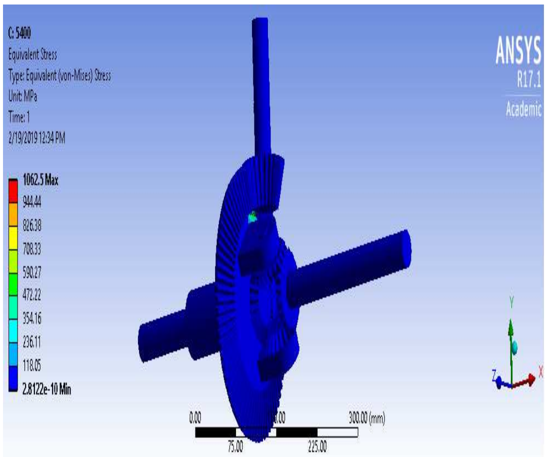



**Figure 8: Von Mises Stress For Ni-Cr Steel = 1062.5 MPA**

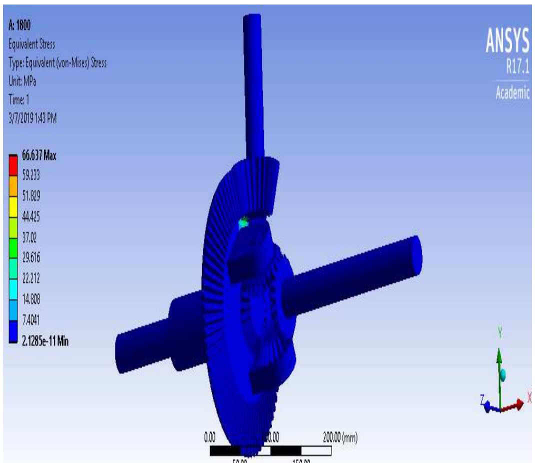



**Figure 9: Von Mises Stress For Titanium Alloy = 66.637 MPA**

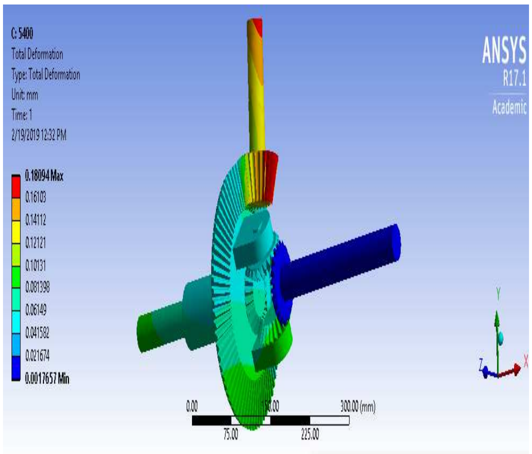



**Figure 10: Total Deformation for Ni-Cr Steel = 0.18094 mm.**

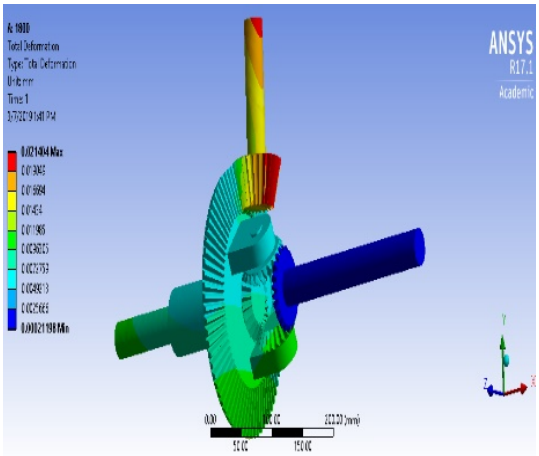



**Figure 11: Total Deformation for Titanium Alloy = 0.021404 mm.**

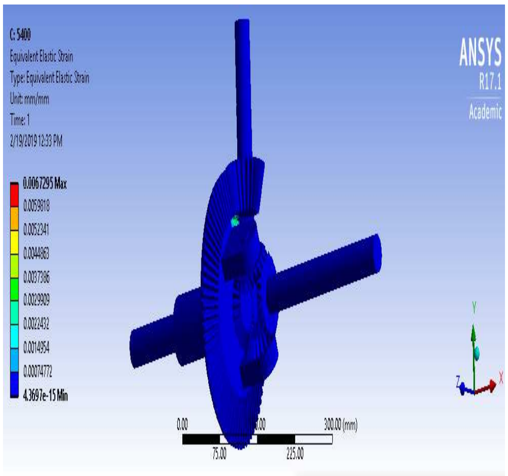



**Figure 12: Maximum strain For Ni-Cr = 0.0067295 For The Titanium Alloy at Torque =390 N-m.**

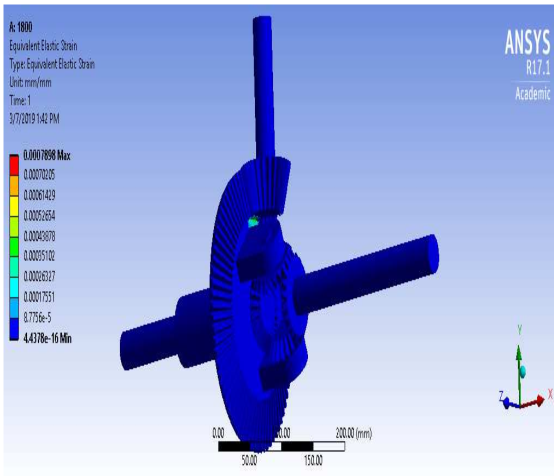



**Figure 13: Maximum Strain for Titanium Alloy = 0.0007898.**

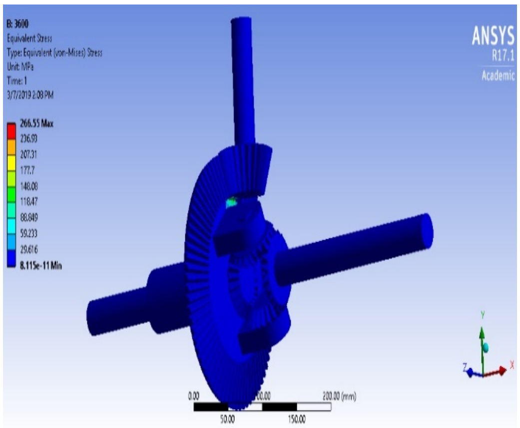



**Figure 14: Von Mises Stress For Titanium Alloy = 266.55 MPA for the Titanium Alloy at Torque =130 N-m.**

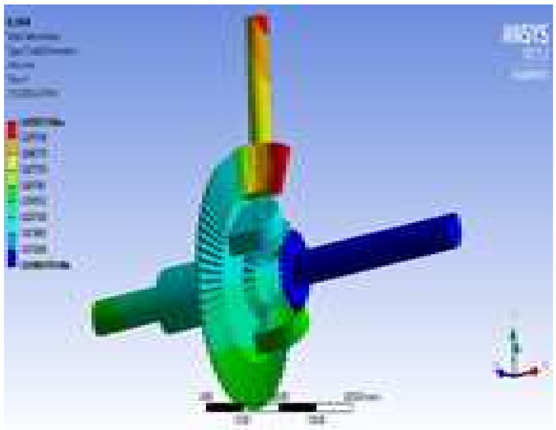


**Figure 15: Total Deformation for Titanium Alloy = 0.085615 mm for the Titanium Alloy at Torque =130 N-m.**

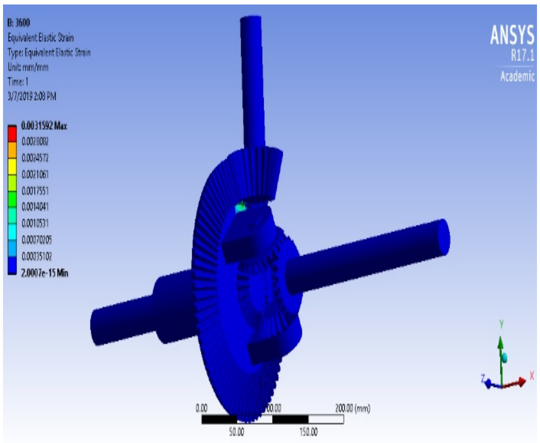



**Figure 16: Maximum Strain for Titanium Alloy = 0.0031592.**

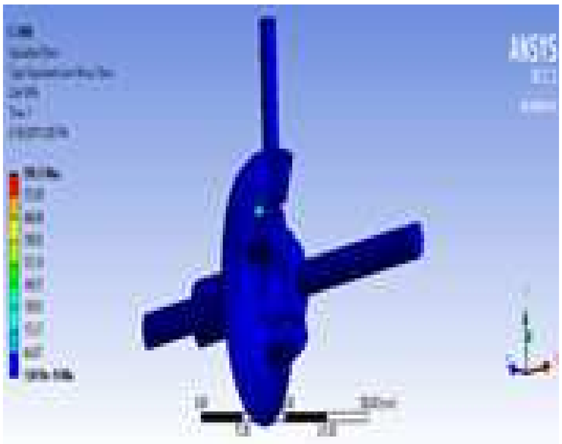


**Figure 17: Von Mises Stress For Titanium Alloy = 599.73 MPA.**

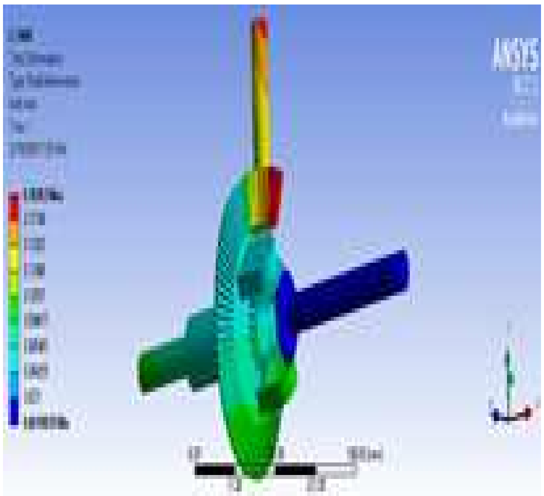


**Figure 18: Total Deformation for Titanium Alloy = 0.19263 for the Monel 500 -Torque = 490 N-m.**

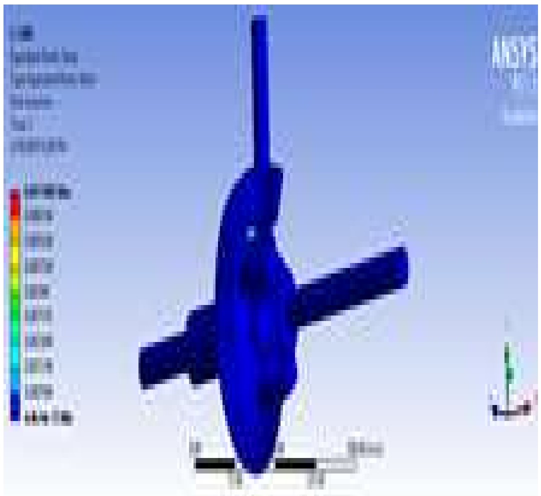


**Figure 19: Maximum Strain for Titanium Alloy = 0.0071082 for the Monel 500 -Torque = 490 N-m.**

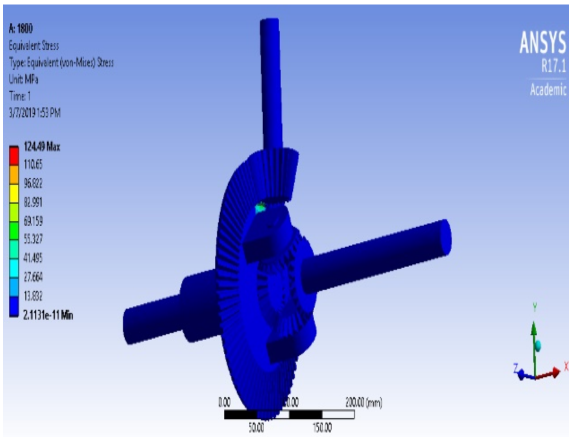



**Figure 20: Von-Mises Stress For Monel 500 = 124.49 MPA For the Monel 500 at Torque = 390 N-m.**

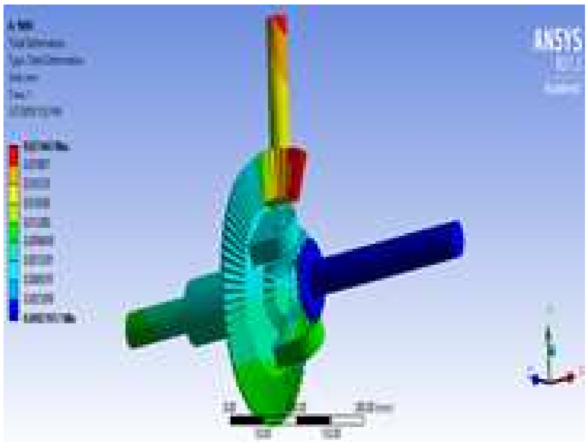


**Figure 21: Total Deformation for Monel 500 = 0.021447 mm For the Monel 500 at Torque = 390 N-m.**

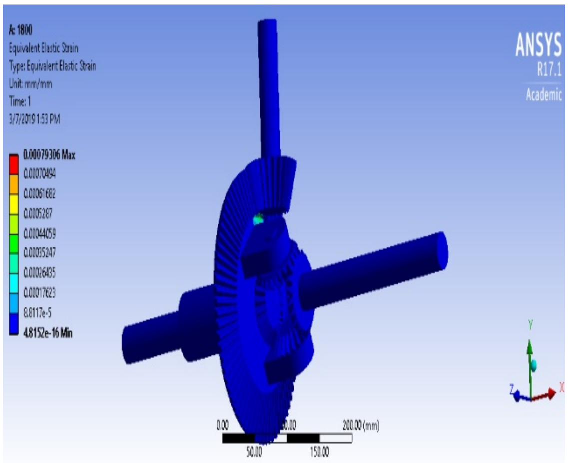



**Figure 22: Maximum Strain for Monel 500 = 0.00079306.**

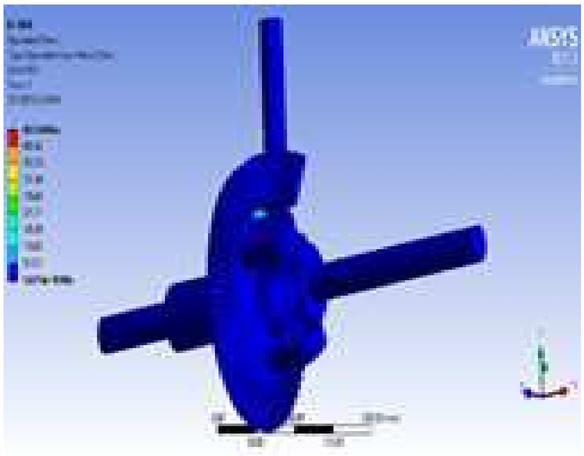


**Figure 23: Von-Mises Stress For Monel 500 = 497.94 MPA.**

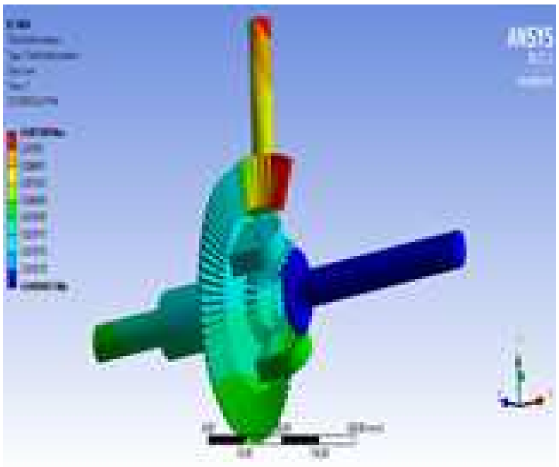


**Figure 24: Total Deformation For Monel 500 = 0.085788mm For The Monel 500 at Torque =130 N-m.**

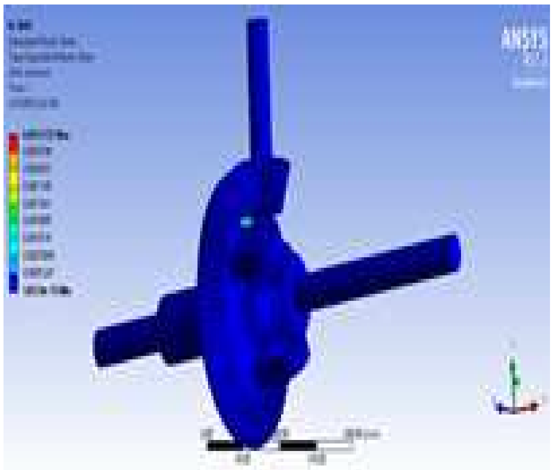


**Figure 25: Maximum Strain For Monel 500 = 0.0031722 For the Aluminium Alloy Torque = 490 N-m.**

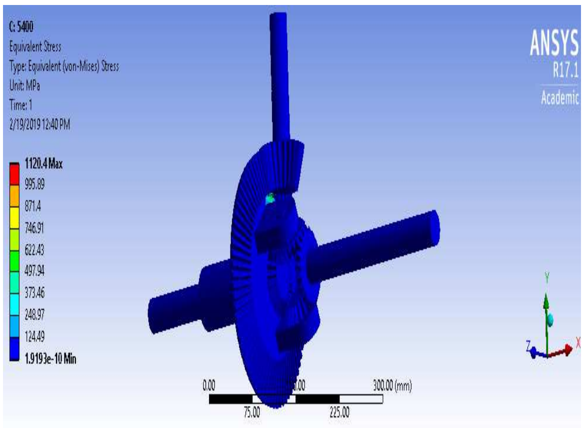



**Figure 26: Von Mises Stress For Monel 500 = 1120.4MPA.**

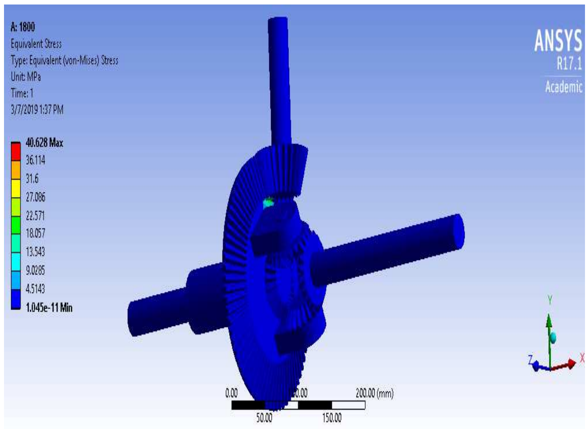
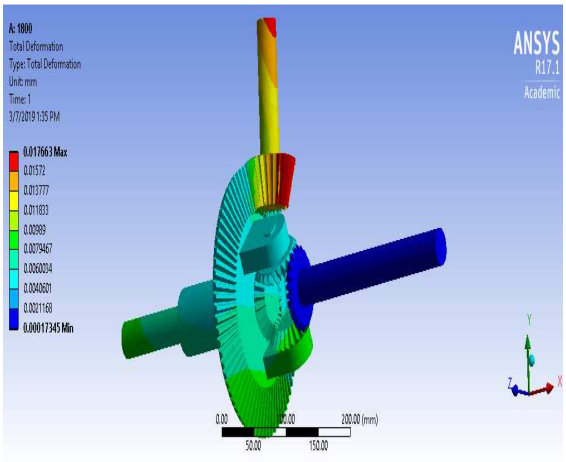



**Figure 27: Von-Mises Stress For Aluminium Alloy = 40.628 MPA.**



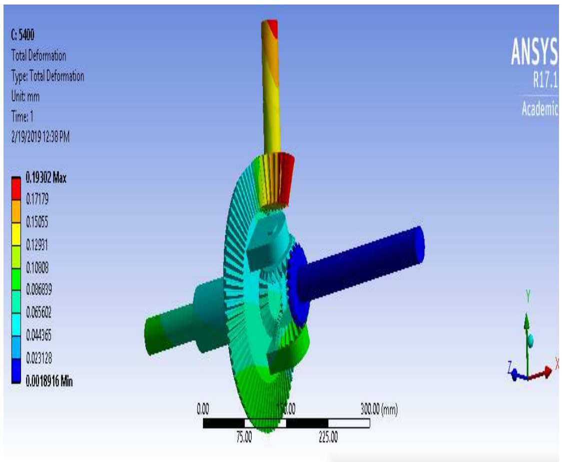
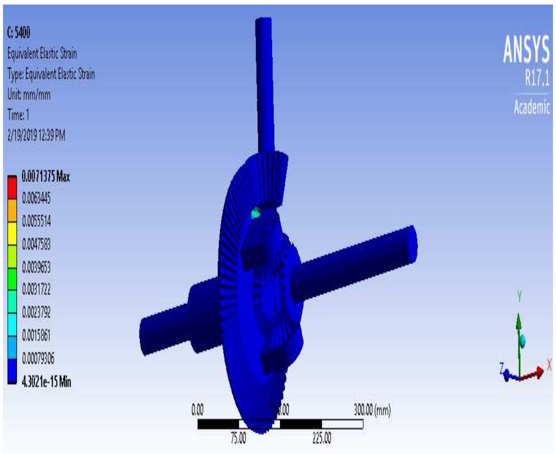




**Figure 28: Total Deformation for Monel 500 = 0.19302 mm.**

**Figure 29: Total Deformation for Aluminium Alloy = 0.017663mm.**



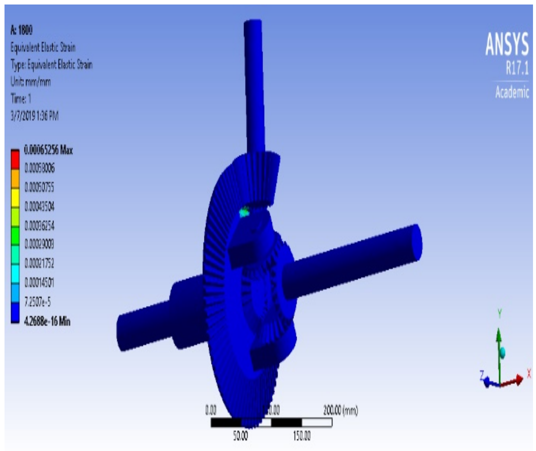
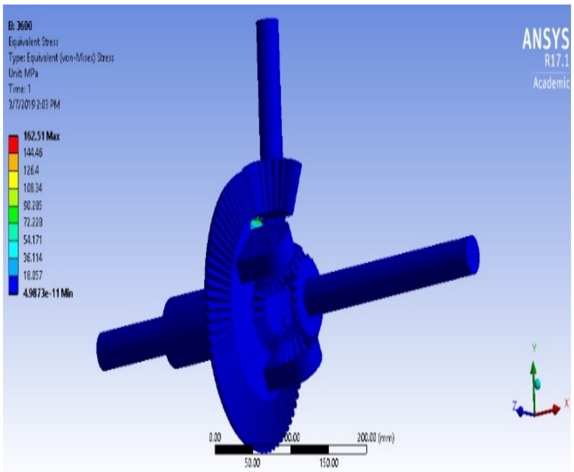




**Figure 30: Maximum Strain for Monel 500 = 0.0071375 for the Aluminium Alloy at Torque = 390 N-m.**

**Figure 31: Maximum Strain for Aluminium Alloy = 0.00065256 for the Aluminium Alloy at Torque = 130 N-m.**



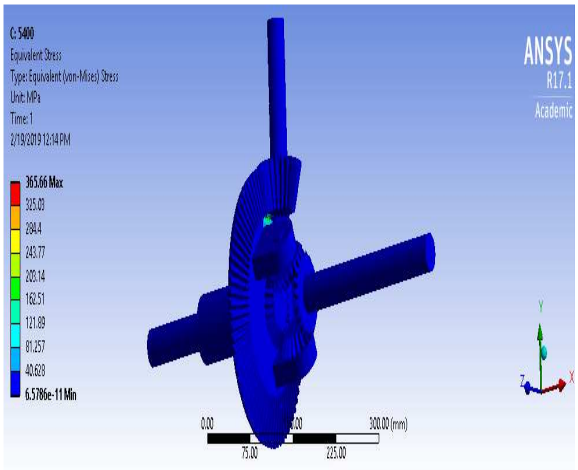




**Figure 32: Von-Mises Stress for Aluminium Alloy = 162.51 MPA.**

**Figure 33: Von Mises Stress for Aluminium Alloy = 365.66MPA.**

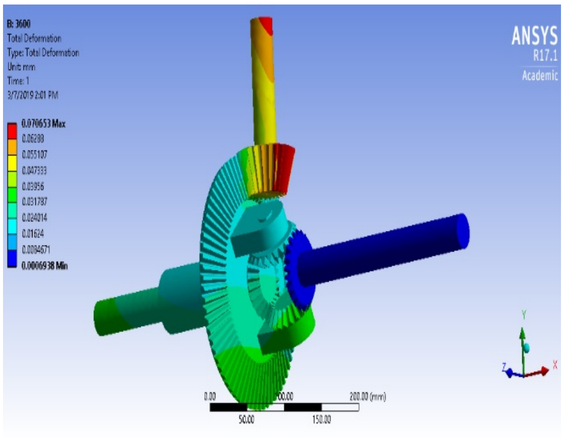



**Figure 34: Total Deformation for Aluminium Alloy =0.070653mm.**

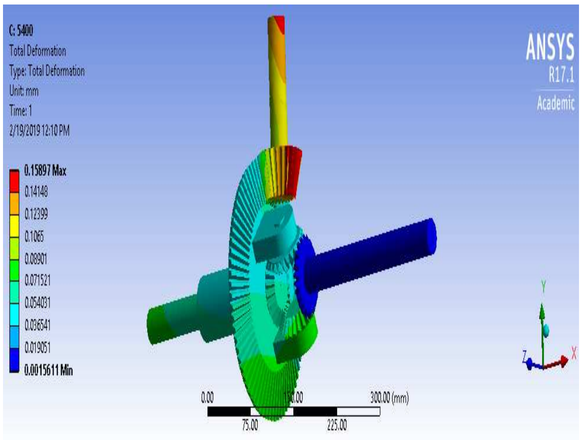



**Figure 35: Total Deformation for Aluminium Alloy =0.15897mm.**

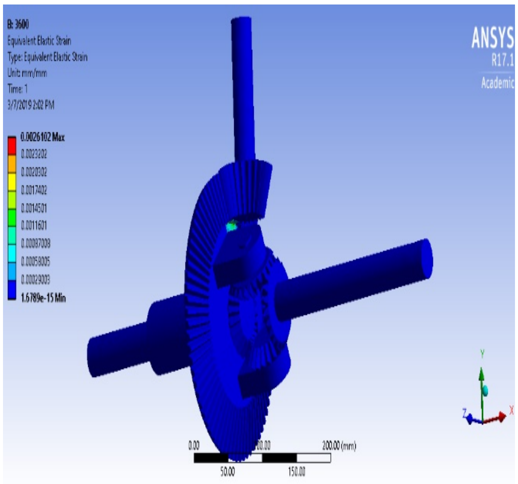



**Figure 36: Maximum Strain for Aluminium Alloy = 0.0026102.**

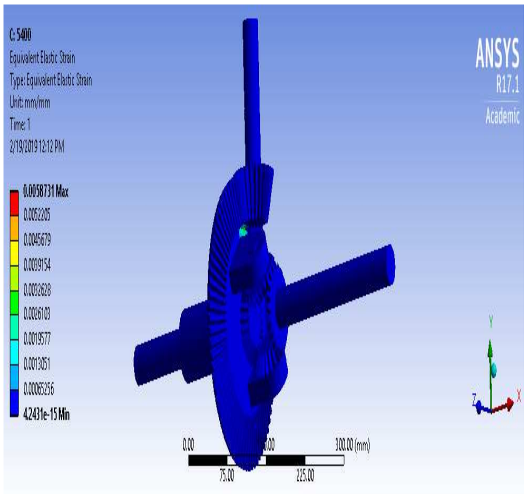



**Figure 37: Maximum Strain for Aluminium Alloy = 0.0058731.**

**Table 3: Comparison Table For Materials Considered**

| Materials | Stress MPA | Strain | Total Deformation (mm) | Density (Kg/m3) |
|---|---|---|---|---|
| Ni-Cr Steel | 1062.5 | 0.0067295 | 0.18094 | 7800 |
| Titanium Alloy | 599.73 | 0.0071082 | 0.19263 | 4620 |
| Monel 500 | 1120.4 | 0.0071375 | 0.19302 | 8434 |
| Aluminium Alloy | 365.66 | 0.0058731 | 0.15897 | 2770 |

## CONCLUSIONS

- The designed Hypoid gear results (i.e. von-misses stress, total deformation and equivalent strain) are compared with the existing gear material, which is Ni-Cr steel. The analysis was done at torque 490 N-m, 390 N-m, and 130 N-m under static loading condition.
- The static structural analysis results shows, the aluminium alloy material is valid replaceable material with Ni-Cr steel because, the aluminium alloy material results have shown lower stress and density.
- By using of aluminium alloy material, the overall weight of the differential gearbox is reduced, hence increasing efficiency.

**Future Scope of the Work**

In the present investigation of static analysis, hypoid gear is analyzed by few materials and speeds.

As a future work, comparing more materials like composite materials, nano coated materials and some advanced materials at various different speeds can be pursued.

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**AUTHORS PROFILE**

**D V Ramana Reddy,** working as Assistant .professor in department of mechanical Engineering, Vardhaman college of Engineering, Shamshabad. He received the B.Tech. degree in Mechanical Engineering from the JNTU, Hyderabad, India, in 2003, and M.Tech degree in the specialization of Machine design (Mechanical Engineering) from the Bharat University from Chennai. Pursuing Ph.D in Andhra University, Visakhapatnam. He current research interest in postbuckling analysis of structural components and composite materials. He has been published 5 international journals. He is a Life Member of the Indian Society for Technical Education (ISTE), Tribology Society of India (TSI) and Society of Automotive Engineers (SAE India).

**G. Revanth Kumar**, received the B.Tech. degree in Mechanical Engineering from the Siddhartha Institute of Engineering and Technology, Puttur, Andhra Pradesh, India, He is now pursuring M.Tech in the specialization of Engineering Design at Vardhaman college of engineering, Shamshabad, Hyderabad.